Pre-Classroom Activities

Activity #1

THE WATER MYSTERY

Materials:

- 1 pt plastic water bottle (the water bottle will last for several tests). If a bottle is not available, use a paper or foam cup. (The cup will last for one, possibly two tests.)
- Nail
- Pencil
- Water
- Pitcher
- Bucket (or conduct the experiment outside)
- Paper Towels (for spills)
- 2 sheets of paper
- Recording sheets

Pre-Lesson Instructions:

1. Begin the class by asking a simple question: Why do we fall?
2. The answer, of course, is “Gravity.”
3. Next, ask your class: “What is gravity?”
4. Have the students give real life examples of their experiences with gravity.
5. Now take a marble and a baseball. Drop the two from the same height, releasing them at the same time. The students should observe that both hit the ground at the same time.
6. Have a few of the students hold the ball and the marble, one in each hand. Ask them which is heavier. The students should conclude that the baseball is heavier. They should also conclude that mass plays no direct role in how fast things fall.
7. Now take two sheets of paper. Have several students hold the two pieces, one in each hand. They should conclude that the two pieces of paper are the same size and weight. Now crumple up one of the pieces of paper into a ball. The students should agree that the mass of the paper has not been changed during crumpling since nothing has been added to the paper. The other piece of paper should be left flat.
8. Drop both pieces from the same height, releasing them both at the same time.
9. Ask students why the crumpled up paper fell faster than the flat paper. Could it be due to gravity or to something else? Remind them about the baseball and the marble!

10. Have the students observe that the two pieces of paper LOOK different. One is definitely WIDER than the other.
11. Now, discuss air resistance. The sheet of paper experienced a larger air resistance than the crumpled up piece of paper. Why?
12. Ask the students to imagine what would happen if they held their hand outside of the window of a moving car palm down. Then ask them what would happen if they held their hand palm to the wind. The palm-to-the-wind hand presents a BIGGER AREA for the wind to act against than the palm-down hand. So, area plays a role in air resistance. (Why did we not notice air resistance with the baseball and the marble? *Answer*: The weight of each was significantly larger than the air resistance acting on it. Such was NOT the case with the two pieces of paper.)
13. Conclude that the crumpled up paper had a smaller force of air resistance acting on it, because it presented a smaller surface area than the non-crumpled paper. Inform the students that, in a vacuum where there is no air resistance, both of these objects would fall at exactly the same rate.

Guidelines: (*To be completed as a demo with the help of students*.)

1. With a nail, punch a small hole close to the bottom of the bottle. Cover the hole with masking tape.
2. Remove the cap from the water bottle.
3. Place a bucket on the ground to catch the water that will drain from the bottle.
4. While holding the bottle over the bucket, fill the bottle with water.
5. Remove the tape and have the students use their recording sheets to record what happens.
6. Tell the students to think about what happened and be prepared to discuss their thoughts.
7. Place your thumb over the hole and refill the bottle.
8. Hold the bottle up high then simply drop it into the bucket.
9. Observe what happens to the stream of water when the bottle is released.
10. Repeat steps 7, 8, and 9. On the data sheet provided have the students record what happened to the water when the bottle was released.

Discussion/Wrap-up:

1. As a class, discuss what results they saw when the bottle was released.
2. Have the students explain all the reasons why they think the water remained in the bottle.
3. Students will need to hold onto their Recording Sheets so they can report their results to the NASA researcher.

Name ________________________________

The Water Mystery Student Recording Sheet *(to be completed and brought to the videoconference)*

1. Watch as your teacher covers the hole with tape, holds the bottle over the bucket, fills the bottle with water, and removes the tape.
2. Observe what happens.
3. Record what happened in the box below.

What happened when the tape was removed?

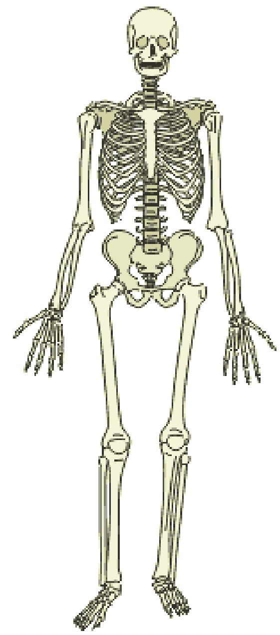
Explain why you think this happened.

4. Watch as your teacher covers the hole with a thumb, fills the bottle with water again, and drops the bottle over the bucket.
5. Observe what happened to the stream of water.
6. Repeat steps 4-5.
7. Record what happened in the box below.

What happened when the bottle was dropped?

Explain why this happened.

Activity #2



BAG OF BONES

Materials:

- Corn Puff Cereal – approx. 4.5 oz per group
- Snack size zip lock bags (*Use small snack-sized bags; large ones take too long to fill and count.)* – 5 per group
- Heavy book – one per group
- Student Recording Sheet – one per group
- Broom and Dustpan for clean up

Focus Questions:

1. Which minerals help to create strong bones?
2. How can we create and maintain healthy bones?
3. What is Osteoporosis?

Introduction (Educators):

1. Discuss Osteoporosis and how good nutrition and exercise are essential for healthy bones.
2. Aging and space flight have a similar effect on the human body; both may lead to **Osteoporosis** or a loss of bone mass. Osteoporosis makes bones weak and fragile, which can make it very easy to fracture or break a bone. In fact, many people do not realize that they have Osteoporosis at all until one of their bones fractures during a minor slip or fall. The activity you are about to complete investigates the effects of Osteoporosis in humans and provides important insight for people living on Earth and in space.

Body:

Getting Ready (Educators):

3. Divide the students into groups of 4. Give each group 5 plastic bags, a sufficient quantity of cereal, a permanent marker, a heavy textbook, and a recording sheet (shown on Page 14).
4. Tell the students that each plastic bag represents a bone. The cereal inside the bone will represent the calcium and cells that make the bone strong. Pieces of cereal represent individual units of bone mass.

5. Using a permanent marker, label the bags 1-5, with Bag 1 representing a healthy bone on Earth.

Building the First "Bone" (Students)

6. Fill Bag 1 with enough cereal so that the bag is very full, leaving as little air as possible in the bag. The bag should not be so full that you cannot close it. Use whole pieces of cereal.

7. Count the number of pieces of cereal you put into the bag, and record this number on your worksheet as Normal Bone Density.

8. Close the bag, and seal it shut; otherwise you may wind up with a very big mess! Call Bag 1: 100% bone mass (normal bone); 0% bone loss.

Building the Remaining 4 Bones (Students)

9. To represent a bone that has lost mass through Osteoporosis, you now need to fill Bags 2 – 5 with less and less cereal, or **bone mass density**, than Bag 1.
   - Bag 2: 90% of original bone mass; 10% of original bone loss
   - Bag 3: 80% of original bone mass; 20% of original bone loss
   - Bag 4: 65% of original bone mass; 35% of original bone loss
   - Bag 5: 50% of original bone mass; 50% of original bone loss

10. To calculate the amount of cereal in Bag 2, calculate 90% of the Normal Bone Density as shown below. Fill Bag 2 with this amount of cereal, which represents a loss of 10% of the bone mass.

Full Bag Count (Number of Pieces of Cereal in Bag 1)	×	0.9	=	Amount of Cereal in Bag 2 (**Bone Mass Density** of Bag 2)

11. Use a similar method to calculate 80%, 65%, and 50% of the Normal Bone Density, and fill Bags 3, 4, and 5 with these amounts. Record the count of "bone" placed in each bag on your recording sheet.

Normal Bone Density =__________ pieces of cereal in Bag 1

Density of Bone 2 = 90% of Bag 1 = ________ pieces of cereal
Density of Bone 3 = 80% of Bag 1 = ________ pieces of cereal
Density of Bone 4 = 65% of Bag 1 = ________ pieces of cereal
Density of Bone 5 = 50% of Bag 1 = ________ pieces of cereal

12. In building each bone, be certain that the air is squeezed out of the bag before sealing the bag shut. Otherwise, the air will act as a cushion and the demonstration will not work as intended.

The Investigation (Students):

13. Now you are ready to witness the effects of a sudden force on normal bones and on weakened bones.

14. Place Bag 1 on a hard surface. The heavy textbook will provide for an unexpected force like a bump or a fall. Lift the book as high as possible and drop it onto the bag-bone. Turn the bag over and repeat the procedure, being careful to lift the book to the same height as before so that the impact force will remain constant.

15. Using the same height each time to maintain a constant impact force, repeat Step 14 for Bags 2, 3, 4 and 5.

16. What happened to the bones? Count the number of whole pieces of cereal left in each bag, and record this number on your student recording sheet. (Students should keep in mind that cereal pieces that have dust on them from other smashed pieces or only a tiny flake broken off should be counted as "unaffected" or whole.)

17. Determine the percentage of bone mass that was left unaffected by the impact. To calculate this percentage, use the formula:

$$\boxed{\text{\# Of Unaffected Cereal Remaining In The Bag}} \div \boxed{\text{Original \textbf{Bone Mass Density} Of The Bag}} \times 100 = \boxed{\text{Percentage of Unaffected Bone}}$$

18. Record the values on your Student Recording Sheet (Page 14).

19. Now, determine the percentage of bone mass that *was* affected. To calculate this percentage, subtract the unaffected bone value percentage calculated in Steps 17-18 from 100.

$$100 - \boxed{\text{Percentage of Unaffected Bone}} = \boxed{\text{Percentage of Affected Bone Mass}}$$

20. Record the values on your Student Recording Sheet (Page 14).

21. Discuss your results in your group and answer the questions on your Student Recording Sheet (Page 14).

Closure (Educators):

22. Use the questions on the student-recording sheet to help the class draw a conclusion.
    a. What happened as the bone density decreased?

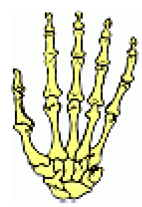
b. What prevented some bone from being affected by the sudden force of the book?
c. What do you think would happen if the plastic bag and cereal were a real bone and a sudden force, like a bump or fall, was applied to the bones?
d. How do you think bone loss can be prevented?

23. Through this experiment students should see why Osteoporosis could cause problems for astronauts – and for people on Earth – if this condition is left untreated. A bone left with mostly whole pieces of cereal is a bone slightly fractured but not broken clean through. The injury is minor and will heal quickly with proper care. The larger the percentage of affected bone, the greater the injury, and the longer the healing time. A bone with 100% damage is a bone fractured in two. This bone might need pins, rods, or even screws in addition to a cast in order to heal properly.

Now discuss the importance of proper diet and exercise. Everyone should eat a proper diet and get plenty of exercise to maintain good health and prevent Osteoporosis. A balanced diet rich in calcium and vitamin D, exercise, and a lifestyle free of smoking and alcohol all help to prevent or alleviate Osteoporosis. Regular bone density testing is often necessary in older people, and, in some cases, medicine is used to help maintain health.

But Osteoporosis also occurs in a reduced gravity environment, despite diet and exercise. NASA is still trying to determine how to counter this condition in astronauts for long-term stays in space. What are the questions that the exercise raises about the possibilities of living on a space station, or going to the Moon or Mars? Please discuss this question as a class.

Lesson adapted from the **Virtual Astronaut**
http://virtualastronaut.jsc.nasa.gov



Name________________________________

Student Recording Sheet

	Before the Experiment		After the Experiment		
Bag	Bone Loss Represented	Bone Mass Density (# of cereal in bag)	# of Unaffected Cereal	% of Bone Unaffected	% of Bone Affected
1	0%				
2	10%				
3	20%				
4	35%				
5	50%				

1. What happened as bone density decreased?

2. What prevented some bone from being affected by the sudden force of the book?

3. What do you think would happen if the plastic bag and the cereal was a real bone, and a sudden force like a bump or a fall was applied to the bones?

4. How do you think we can prevent bone loss?

Resources

Microgravity: A Teacher's Guide with Activities in Science, Mathematics, and Technology (Grades 5-12)
This educator guide contains excellent background information accompanied by classroom activities that enable students to experiment with the forces and processes microgravity scientists are investigating today.
http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Microgravity/Microgravity.Teachers.Guide.pdf

Microgravity: Earth and Space (Grades 3-12)
This NASA educator guide contains general information about Microgravity, classroom activities, and student worksheets. The activities are meant to be done by project teams and are grouped by grade levels 3-5, 6-8, and 9-12.
http://spacelink.nasa.gov/products/Microgravity-Earth.and.Space/

Inner Space in Outer Space
This Teacher's guide will let teachers and students explore the same aspects of human physiology studied on board the ISS. You will learn about the different systems of the human body; how they work on Earth and how they change in microgravity.
http://virtualastronaut.jsc.nasa.gov/107/inner.pdf

The Brain in Space
The study of the ways in which the body's brain, spinal cord, and network of nerves control the activities of animals and humans is called neuroscience. This guide targets a high school audience and provides background material and activities related to NASA's Neurolab research.
http://spacelink.nasa.gov/products/The.Brain.in.Space/

Background Information

WHAT IS MICROGRAVITY?

The term, ***microgravity*** literally means *small gravity*, from the roots *mikros* (Greek) small + *gravity*. A microgravity environment (or μg), is defined as any environment where gravity levels are significantly reduced compared to those we experience at Earth's surface. We refer to Earth's surface environment as a one-gravity (1-g) environment.

GRAVITY IN GENERAL

Gravity is often erroneously thought of as a force – i.e., the "force of gravity." Referring to gravity as a force is a common misnomer that leads to confusion for students trying to make a serious study of gravity in physics.

Properly so-called, gravity is *acceleration* – which is exactly why it is so mysterious. A small test object, placed near any mass anywhere in the universe and left to its own accord, will accelerate toward that mass. (More correctly, the two masses will accelerate toward each other.) We usually say that the test mass is moving "under the influence of gravity," although it would probably be more correct to say that its moving as it does shows the presence of gravity in its vicinity.

At the Earth's surface, the gravitational acceleration amounts to about 9.8 m/s^2 (32 ft/s^2). When the mass of a test object (in kg) is multiplied by this acceleration, we calculate the *weight* of the object, which may be thought of as a force acting on the object since, by Newton's Second Law of Motion, the product is a mass times an acceleration. But it is very important to remember that weight is a *derived* quantity and is *different* for an elephant than for a feather, while the acceleration of gravity *is the same for all*. Thus, the elephant and the feather will fall (accelerate) at exactly the same rate, even though the force of gravity on each is very different.[1] This concept lies at the heart of understanding zero-g and micro-g.

Your body is accustomed to a one-gravity (1 g) environment because you have grown up and lived all your life in 1-g. Your bones, muscles, heart, nervous system, etc., are all "tuned" to this level of gravity. If gravity were suddenly to change, you would feel radically different. How could you experience such a change? Well…have you ever ridden on a roller coaster? If so, do you remember how you felt on the first big hill? You were in near free fall on that hill, and free fall environments are micro-g environments. In effect, gravity was "turned off" for you for a second or two! Did you feel different? If not, we had better check to see whether or not you are really alive!

We take gravity for granted on Earth. You have probably heard the adage**,** "What goes up, must come down**,**" and you have probably experienced the effects

of gravity when you have fallen off a bike or a snowboard. We all expect a football or snowflake moving through the air to eventually fall to the ground.

So what exactly DOES happen when gravity changes?

If we were to shut gravity completely off for longer than a second or two so that we could observe at our leisure, then we would see objects moving uniformly in straight lines or remaining at rest unless acted upon by a force (a push or a pull). Newton's First Law of Motion in fact, describes this type of motion, and it is routinely experienced in orbital environments such as in the Space Shuttle or the Space Station. If we were now to turn gravity back on, the First Law of Motion would have to be amended somewhat because we would now see objects moving in complicated curves, speeding up and slowing down, and so on; and objects at rest would not necessarily remain at rest!

Sir Isaac Newton (1642-1727) correctly stated that gravity governs motions of objects everywhere in the universe; and indeed it does! Newton described gravity as an acceleration associated with the presence of matter. If there is a large concentration of matter at some location in space, say, a star or a planet, then there is gravity inside and outside of the concentration as well as at its surface. Newton succeeded in writing a mathematical description of gravitation that helped to enable the rise of the modern age of technology.

Newton also erroneously thought of gravity as a force of attraction. He understood that this idea of a force of gravity introduced significant problems into his overall theory, but he could find no way out. After much thought and labor, he wrote, in his great work, *The Principia*, "…the matter is not entirely hopeless…" and left the question open to future generations to grapple with.

The central problem is this: if gravity is a force, then it must be a peculiar kind of force that is able to act *without anything having to touch anything else* – a force without contact, or *action at a distance*. A force is a push or a pull. Imagine pushing or pulling something without ever coming into contact with it! No rope, no chain, no "hands on." Simply "will" the object to move. And your will must be transmitted instantaneously (that is, without any delay) across space.

For almost 300 years following Newton's great work, physicists wrestled with this problem of action at a distance. Ernst Mach (1836-1916) wrote one of the most eloquent papers on the subject. But full resolution did not come until 1917, when Dr. Albert Einstein published his now famous paper on General Relativity, essentially re-writing all of Newton's work. It is important to note that Newton did not fail – in fact, he had succeeded brilliantly for his time, and Einstein gave him highest praises for what he had accomplished**:**

"If I have seen further than others," he once said, "it is because I stand on the shoulders of Newton."

But Newton lacked the knowledge that was yet to arise in the centuries following his great work. Had he had that knowledge, there is no telling how far he would have been able to go! The rest of this article will use the idea of a force of attraction and thus follow Newton. Please note, however, that, in doing so, great care has been taken not to lead the reader into error.

When conceptualized as a force, gravity becomes an attraction existing between all pairs of masses everywhere throughout the universe. Essentially, where there is mass, there is gravity. There is gravitational attraction between every pair of stars that you see in the night sky. There is gravitational attraction between the earth and the moon, and between the moon and the sun. There is even gravitational attraction between you and this page because both you and the page possess mass and, therefore, gravity!

Well then, why don't you feel yourself being "pulled" toward the page? Because the mass of the page is miniscule compared with the mass of the Earth:

- The mass of the page might be all of one gram (1 gm). The mass of the Earth is 6,000,000,000,000,000,000,000,000,000 gm (that's 6 followed 27 zeros!). Thus, the gravitational effects of the Earth versus those of the page occur on a ratio of 6,000,000,000,000,000,000,000,000,000 to 1.

Because Earth is so massive, its attraction is much greater than the attractions of other objects around us. Newton mathematically described the attraction between two objects of masses m_1 and m_2 separated by a distance r as shown in the box. Sir Henry Cavendish (1731-1810) modified Newton's law to include a gravitational constant, thus producing the familiar equation still in use today.

Newton's original law

$$F \propto \frac{m_1 m_2}{r^2}$$

F = force

$\propto$ = "proportional to"

m_1 = mass of the first object

m_2 = mass of the second object

r^2 = distance between the objects

Henry Cavendish's modification

$$F = G \frac{m_1 m_2}{r^2}$$

$G = 6.67 \times 10^{-11}\ Nm^2/kg^2$

Cavendish added G, the universal gravitational constant. Note that multiplying the two masses cancels the $1/kg^2$ in G, and the $1/r^2$ cancels the m^2 in G, leaving just Newtons (N) as the final result.

Newton's Law and Cavendish's modification tell us that the greater the masses m_1 and/or m_2, the greater the attraction F between them. Doubling one of the masses doubles the attraction. Tripling one of the masses triples the attraction. Tripling both masses increases the attraction by a factor of 9. And so on.

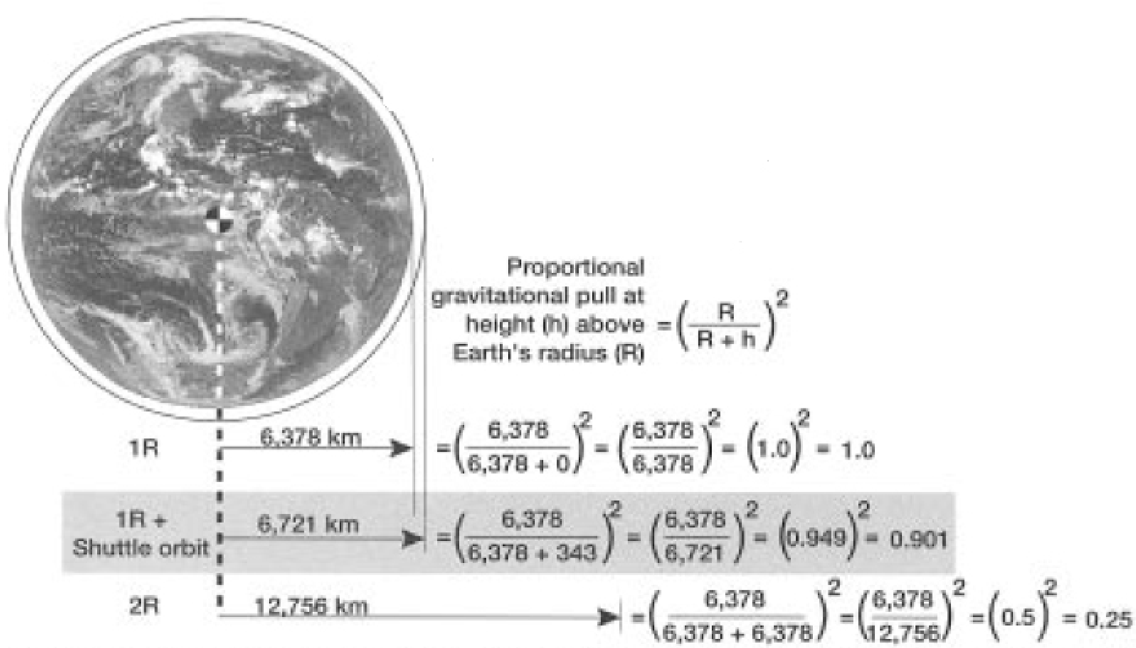
The law of gravitation also tells us that the farther apart the objects are from one another, the less the attraction between them. Because the separation appears in the denominator *and is squared*, we observe that doubling the separation decreases the attraction by a factor of 4; tripling the separation decreases the attraction by a factor of 9, and so on. Such a law is called an *inverse-square law* and is a familiar breed of law in many areas of physics!

With Newton's Law of Gravity in hand, you now possess the "machinery" to determine how gravity changes as you move away from Earth's surface. Recall that, when standing on Earth's surface at 1 gravity or 1 g, the acceleration of an object toward the center of Earth is approximately 9.8 meters per second squared (m/s^2) or 32 feet per second squared (ft/s^2). Your mass and this acceleration of gravity when multiplied together determine your weight. Please remember that while your weight is subject to change with local gravity, your mass is not. Your mass is the measure of the total amount of "stuff" making you up, and you neither gain nor loose "stuff" when you move about!

Earth's gravitational attraction is *reduced* via the inverse square law when you move away from Earth. Let us represent the Earth's radius by a capital "R." On Earth's surface, we will set R=1; i.e., we say that we are at *one "Earth-radius"* from the center of our planet. If you now travel out to a distance of two Earth-radii, that is, to R =2, Earth's gravitational pull drops to ¼ what it was on Earth's surface. Thus, if you weighed 120 pounds at R = 1, you will weigh 30 pounds at R = 2.

ABOARD THE SPACE SHUTTLE – LIFE IN MICRO-G

At Space Shuttle altitude (343 km (212 mi)), the astronauts and the Shuttle are still under the influence of about 0.9 of Earth's surface gravity, that is, they are falling towards Earth with an acceleration of about 8.8 m/s^2.



Why doesn’t the Shuttle simply fall back toward Earth? Because it is traveling forward at just the right speed [more than 27,000 km/h (17,000 mph)] while simultaneously falling towards Earth to avoid ever hitting Earth. We say that the Shuttle is in orbit. It is moving along a trajectory *that follows the curvature of Earth*. Because the Shuttle is in free fall while in orbit around Earth, a microgravity environment is established everywhere aboard the Shuttle. Remember that the condition of microgravity occurs throughout an object whenever an object is in free fall.

Let us see why this is so. Remember the elephant and the feather? Both fall at the same rate when allowed to fall freely. Thus, the elephant sees the feather always next to him, and the feather sees the elephant always next to it. As far as either one of them is concerned, they might as well both be at rest with respect to one another. But being at rest and remaining at rest is only possible where there is no gravity. Thus, the elephant and the feather are both entitled to imagine themselves in a *gravity-free region of space*, and may continue doing so right up to the time that they hit bottom. At the point of hitting bottom, we graciously allow the curtain to close so as not to have to see all that happens immediately after…!

You have no doubt heard that the astronauts can move freely in space because they are so far from Earth that gravity has little effect, or that there is no gravity. Now you know that is not true. The Shuttle and the astronauts and everything else on board are constantly falling toward the Earth with an acceleration of about 8.8 m/s^2. Aboard the Shuttle, in a condition matching a gravity free region of space, the astronauts are able to move about freely. In fact, their motions are aptly described by Newton’s First Law of Motion mentioned earlier.

It might be interesting to note in passing how the Space Shuttle acquires its enormous speed of 17,000 miles per hour in the first place. It does so by using rocket engines that fire with millions of pounds of thrust during launch, liftoff, and ascent above the Earth’s atmosphere. The vehicle initially ascends above the atmosphere to get above those regions where atmospheric drag is a factor in flight. It then turns eastward, toward the local horizontal and continues to accelerate to orbit. Once the engines are off, the Shuttle actually begins to orbit (i.e., to fall freely toward Earth while simultaneously moving around Earth’s curved surface) and there it remains, going ‘round and ‘round, until the descent engines are fired, reducing the vehicle’s speed and allowing it to fall back to Earth and so descend to the surface.

Sir Isaac Newton beautifully explained how a satellite could be made to orbit Earth. It is worth taking a moment to follow his thought. Newton argued that if you placed a cannon at the top of a very tall mountain then fired a cannonball parallel to the ground, the ball would move in an arc and fall to Earth because of the presence of gravity. If you increased the speed of the cannon ball, it would travel farther before landing i.e., the arc along which it traveled would flatten out. And if the cannonball were fired with sufficiently high speed, then the arc would flatten out to match the curvature of Earth’s surface, and the ball would achieve a state of continuous free fall, or orbit; it would fall *entirely around Earth*. Provided no force other than gravity acted on the cannonball’s motion, it would keep circling Earth in orbit.

How does it feel to be aboard the Space Shuttle while it is in orbit? Well…remember the roller coaster we mentioned earlier? Imagine feeling that first hill, not for just a couple of seconds, but continuously for a week or two! You would eat, work, sleep, do everything that you had to do while feeling like your stomach was somewhere in your chest cavity and your head was trying to swell beyond its accustomed boundaries. Obviously, careful accommodations are required for astronauts to live in space without injuring themselves in an environment that is so radically different!

Meals are eaten in micro-g much as they are eaten on Earth. Swallowing is not affected by a reduction in gravity. Swallowing relies on a process called peristalsis, a contractile wave motion of the esophagus that “pushes” food from the throat to the stomach. Sleeping in micro-g is affected by micro-g. Since there is no up or down in micro-g (remember “up” and “down” can only be defined in reference to local gravity), the astronauts are free to sleep in any position they desire. The only constraint is that they must sleep in specially prepared sleeping bags Velcro-ed to the Shuttle walls. Otherwise, they would “float” about and collide with one another.

If you were aboard the Space Shuttle, your workday would consist of conducting experiments, exercising, taking meals, enjoying rest periods, and taking pictures with various types of cameras including the IMAX camera. Once you became acclimated to your new environment (a process that may take a day or so) you would find it an exhilarating experience and very enjoyable.

What kinds of science could you conduct in a microgravity environment that would be different from science done in normal gravity conditions? You might explore various properties of materials, or the behavior of living organisms such as fish or insects. You might also study the effects of reduced gravity on human physiology, acquiring knowledge that will be essential if we are ever to send humans to such distant places as Mars.

Before moving on, let’s look a little more closely at one of these areas – the area of metal alloying. If you were to melt two different metals on Earth, then mix them to form a new metal or alloy, you would quickly find that the process works only if both metals have similar densities. The density of a material is a measure of how much mass the material has packed in a convenient unit volume of space and is usually measured in units of kg/m^3.

On Earth, if two metals of significantly different density were mixed in the molten state, the less dense metal would always float to the top unless the metals were actively and continuously mixed. Italian salad dressing does much the same thing after it has been shaken then set aside. We say that the dressing “settles.” This settling occurs because, in gravity, the heavier fluid sinks below the lighter fluid forcing it to “float to the top.” In orbit, in a micro-g environment, the two metals mix much more readily and stay mixed, allowing formation of alloys which often display unique properties, i.e., properties not available on Earth.

NASA scientists are conducting microgravity research in areas such as biotechnology, combustion science, fluid physics, fundamental physics, and materials science. Microgravity can help us learn more about how free fall conditions affect our bodies. It also gives us unique opportunities to investigate new materials such as alloys, crystals, and medicines.

How Do We Create Microgravity on Earth?

Japanese astronaut Chiaki Mukai sails through the entrance of the Space Shuttle's Spacelab module.

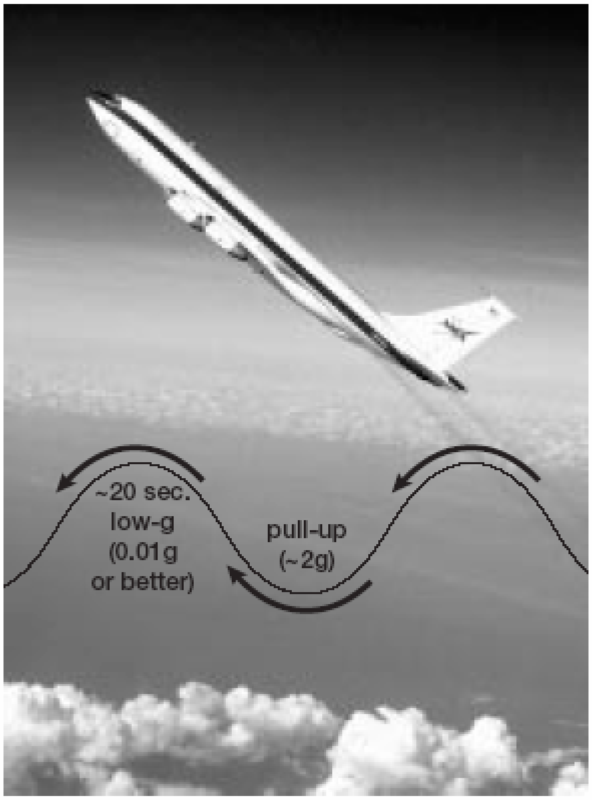
Orbiting spacecraft provide the best laboratories for long periods of microgravity research. Experiments lasting for more than two weeks are possible with the Shuttle. Once the International Space Station has a permanent crew aboard and is ready for research, experimentation time can be extended to months. An important advantage of having longer periods of time available is that scientists have the ability to conduct research as it is conducted on Earth. Experiments can be performed multiple times with different parameters. Thus scientific researchers will be able to gather comprehensive data.

On earth, scientists and engineers also use drop towers, aircraft, and rockets to achieve short periods of microgravity. Doing so provides much shorter experiment times, but also affords much lower cost. Everything in life is a trade-off of some kind!

Dropping a payload down a deep hole on Earth creates free fall conditions within the payload for the duration of the fall. Researchers at NASA and in other facilities around the world use drop towers and drop tubes to create microgravity environments. NASA's John H. Glenn Research Center in Cleveland, Ohio, has two-drop facilities. The 132-meter (430-ft) drop tower creates a microgravity environment for about 5.2 seconds while the 24-meter (79-ft) drop tower provides 2.2 seconds of microgravity per drop.

Experiments in the 2.2-second Drop Tower are assembled on a drop frame structure and enclosed in an aerodynamically shaped box called a drag shield that protects the experiment. The drag shield/experiment assembly is hoisted to the top of the tower and released. The entire assembly falls freely in the open environment of the tower. The experiment is isolated from aerodynamic drag because it is contained within the drag shield but not attached to it. During the drop, the entire assembly falls 24 meters, and the experiment freely falls a distance of 20 cm (0.65 ft) within the drag shield.

The package is slowed and stopped by a 3-meter (10-ft) tall air bag. Battery packs provide onboard power to the experiment. High-speed motion picture cameras, video cameras, and onboard computers collect data for the investigator. The 5.2-second Zero-Gravity Facility drops larger packages in a deep vacuum chamber. The longest drop time (10 seconds) is in Japan where a vertical mineshaft was converted to a 490-meter (1,607.2-ft) drop facility.

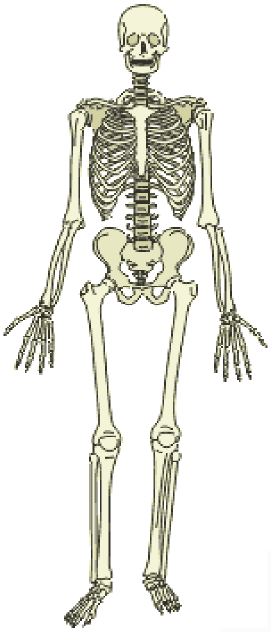


The roller-coaster ride of the KC-135 (*aka* the Vomit Comet) is another technique for providing brief periods of low-g to test experimental hardware and to train astronauts (below).

You can also create a reduced gravity environment in an airplane as it flies in a roller coaster trajectory or parabolic path. NASA astronauts train for orbital missions in a modified KC-135 (a military tanker version of the Boeing 707 passenger jet), also called the Vomit Comet! A typical flight lasting from 2 to 3 hours gives crewmembers about forty 20-second periods of microgravity. The plane does a series of pull-up and pushover segments as it moves along its roller coaster path in the air to produce temporary free fall. Many people get airsick, as you might imagine. While the conditions of microgravity are limited in an airplane because of turbulence and flight-control limitations, the advantage is that researchers can ride along with their experiments.

Small sounding rockets are another way to create microgravity. Sounding rockets experience free fall conditions for 6 to 7 minutes as they follow suborbital parabolic paths. Free fall exists during the rocket's coast above Earth's atmosphere, where it is free of drag.

Adapted from From: Microgravity: Earth and Space
An Educator's Guide with Activities in Technology, Science and Mathematics



AFFECT OF MICROGRAVITY ON BONES

Life in the microgravity environment of space brings many changes to the human body. The loss of bone and muscle mass, change in cardiac performance, variation in behavior, and body-wide alterations initiated by a changing nervous system are some of the most apparent and potentially detrimental effects of microgravity. Changes to bone are particularly noticeable because they affect an astronaut's ability to move and walk upon return to Earth's gravity.

Structure and Function of Bone

Bone is a living tissue. It is dynamic, responsive to disease and injury, and self-repairing. Bone has both an organic component and an inorganic component. The organic component is composed mainly of collage, long chains of protein that intertwine in flexible, elastic fibers. Hydroxyapatite, the inorganic component, is a calcium-rich mineral that stiffens and strengthens the collagen. Together, the interwoven organic and inorganic components of bone create a sturdy yet flexible skeletal structure.

The body is constantly breaking down old bone, and replacing it with new bone. Bone is formed by cells called osteoblasts. These cells lay down new mineral along the surface of bone. Osteoclasts, large multinucleate cells, break down old bone, and are in part responsible for releasing calcium into the bloodstream. In a healthy individual on Earth, bone is formed at the same rate at which it is broken down, so there is never an overall loss of bone mass. This process changes as a person grows older, or enters microgravity for an extended period of time.

On Earth, Bones Perform Four Basic Functions

- **Mechanical support:** The skeleton supports soft tissue and the body's weight. Many bones also act as levers for muscles, enabling movement.
- **Storage of essential nutrients:** Bone stores much of the calcium received from the diet. The calcium is stored in hydroxapatite (the principal bone salt which provides the compressional strength of vertebrate bone). Between meals, the body maintains a constant concentration of calcium by absorbing it from bone and releasing it into the bloodstream. This constant calcium level in the bloodstream allows proper neural muscular, and endocrine (hormone) functioning, as well as other cellular activities (e.g., blood clotting). From the bloodstream, different organs and systems of the body take up the calcium. When the body absorbs too much calcium from bones the skeleton can become thin and weak. Bone is also a good source of phosphate, hydrogen, potassium, and magnesium. Like calcium, these minerals are used by many systems of the body for a wide range of purposes.
- **Production of blood:** In addition to essential minerals, bone is also the storage site of marrow. Marrow is important for the formation and development of red and white blood cells and platelets.

- **Protection**: The skeleton houses and protects the brain, spinal column, and nerves. Many bones, especially the ribs, also protect the internal organs.

Bone and Microgravity

Some of the processes and functions of bones change after the astronaut has lived in microgravity for several days. In space, the amount of weight that bones must support is reduced to almost zero. At the same time, many bones that aid in movement are no longer subjected to the same stresses that they are subjected to on Earth. Over time, calcium normally stored in the bones is broken down and released into the bloodstream. The high amount of calcium found in astronaut's blood during space flight (much higher than on Earth) reflects the decrease in bone density, or bone mass. This drop in density, known as disuse osteoporosis, leaves bone weak and less able to support the body's weight and movement upon return to Earth, putting the astronaut at a higher risk or fracture.

This bone loss begins within the first few days in space. The most severs loss occurs between the second and fifth months in space, although the process continues throughout the entire time spent in microgravity. Extended stays on Mir have resulted in losses of bone mass of as much as 20%. Astronauts regain most of their bone mass in the months following their return from space, but not all of it.

The exact mechanism that causes the loss of calcium in microgravity is unknown. Many scientists believe that microgravity somehow causes bone to break down at a much faster rate than it is built up. However, the exact trigger for this rate change has not been found. Researchers are currently pursuing multiple lines of research, including hormone level, diet, and exercise, in order to determine exactly what causes- and may control or prevent-osteoporosis during space flight.

Another type of osteoporosis is a problem on Earth. As we grow older, the body begins to absorb bone much faster than it produces new bone. This leads to a lowered bone density, the same effect that microgravity has on astronauts. As a result, bones become more fragile and are more susceptible to fractures, especially in the hip, spine, and wrist. In many cases, people do not know that they have osteoporosis until their bones become so weak that an accidental bump or fall causes a fracture. Just as astronauts eat a careful diet and get plenty of special exercise in space to prevent disuse osteoporosis, steps can be taken to prevent osteoporosis on Earth. A balanced diet rich in calcium and vitamin D, exercise, a lifestyle free of smoking and alcohol, bone density testing, and medication all prevent or alleviate osteoporosis.

Information from: ***http://virtualastronaut.jsc.nasa.gov***